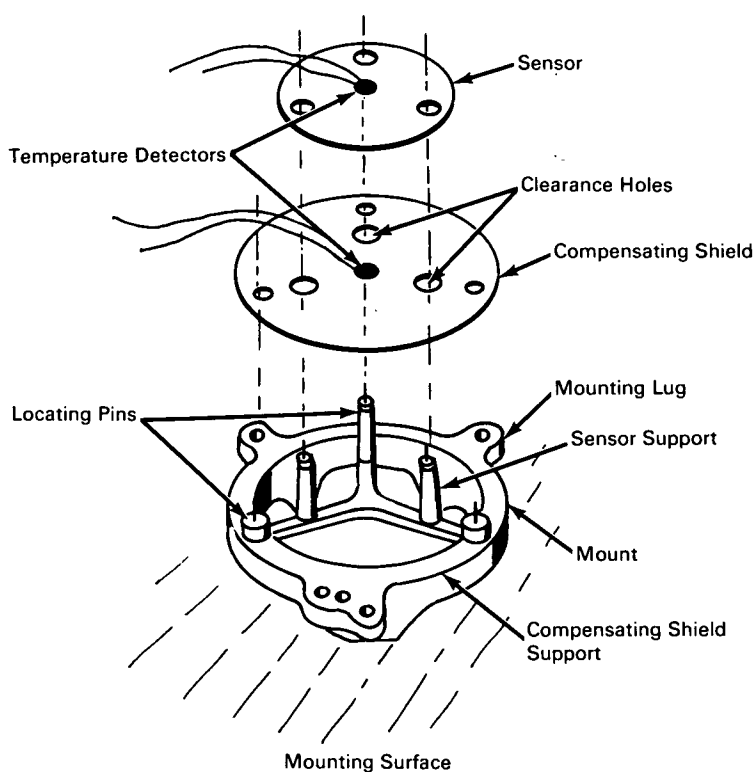


NASA TECH BRIEF



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Calorimeter Accurately Measures Thermal Radiation Energy



The problem: To design a calorimeter that will accurately measure steady-state and transient, low-level thermal radiation energy (down to approximately 0.007 to 0.37 Btu/ft²/sec).

Radiant energy is usually measured by means of a slug calorimeter or a heat sink (thermal gradient) calorimeter. The slug calorimeter has the disadvantage

of being unable to detect rapid energy transients. The basic heat sink calorimeter does not provide an accurate measure of the incident energy after extended exposure to a time-varying heat source. When used for the measurement of low-level radiation energy, both types of calorimeter introduce appreciable errors from the following sources: (1) heat losses through lead

(continued overleaf)

wires, insulation, and connectors: (2) heat storage effects due to the relatively large thermal masses required for the sensor (in the slug calorimeter) and the heat sink (in the heat sink calorimeter); (3) degradation of the sensor characteristics with time; and (4) outgassing effects when the calorimeters are used in high vacuum.

The solution: A radiation calorimeter incorporating a compensating shield, located between the sensor and the calorimeter mount, to intercept sensor heat losses and to provide a reference for determining a correction factor.

How it's done: The calorimeter consists of a mount, a sensor, a compensating shield, and two temperature detectors (thermocouples or resistance thermometers). The mount is made of a material having low thermal conductivity, low specific heat, low outgassing, and good dimensional stability over a large temperature range. A metal having good thermal conductivity is used for the sensor and compensating shield in order to minimize thermal gradients within them. The upper surfaces of these elements, which face the radiation to be measured, are coated with a material of high absorptance. For use in a vacuum, the assembly is of open design to eliminate outgassing products.

The temperature difference between the sensor and compensating shield, as indicated by the temperature detectors, is proportional to a correction factor K , which in turn is proportional to the heat losses. This factor is determined from either calculations or calibration data. For highest measurement accuracy, K must be kept small. This is accomplished by (1) coating the undersurfaces of the sensor and compensating shield with a low-emittance material (e.g., gold); (2) making the compensating shield larger than the sensor so that the exposed surface of the shield will also receive direct radiant energy, thus reducing the temperature gradient between the sensor and shield; and (3) providing long thermal conducting paths between the calorimeter elements and the mounting surface.

With the properly chosen design parameters, the calorimeter will detect rapid transient changes in the incident energy in accordance with the following simplified version of the slug-type calorimeter equation:

$$H = \sigma (T + K)^4$$

where H = the equivalent incident blackbody energy, σ = Stefan-Boltzmann constant, T = absolute temperature of the sensor, and K = the correction factor.

Notes:

1. This calorimeter combines the major advantages of other radiation calorimeters which feature small size, resistance to mechanical shock, rapid response, and simplicity of data evaluation.
2. The calorimeter may be used for either intermittent or continuous readings.
3. Degradation of the coatings will not seriously affect the accuracy of the calorimeter, as the energy measurements are not directly related to sensor emittance or absorptance.
4. The calorimeter is adaptable to quantity production at considerable savings in assembly cost and calibration time compared to commercially available radiation calorimeters.
5. It should have application whenever rapid-response, highly accurate thermal radiation measurements are required in vacuum or atmospheric environments.
6. Inquiries concerning this invention may be directed to:

Technology Utilization Officer
Langley Research Center
Langley Station
Hampton, Virginia, 23365
Reference: B66-10058

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code AGP, Washington, D.C., 20546.

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